Well Water Quality and Treatment in Nova Scotia

by
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Nova Scotia
Department of the Environment
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Province of Nova Scotia
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Preface

This report on Well Water Quality and Treatment in Nova Scotia is prepared for public information and assistance as part of the Nova Scotia Department of the Environment's effort in promoting efficient development and wise use of our water resources to support the social and economic development priority of the province. By publishing this report, we hope to clarify some of the mysteries and misconceptions surrounding well water quality problems and their remedial measures in Nova Scotia. We stress the importance of the understanding of the basic water quality problems and available treatment technologies so that sound decisions can be made.

During the preparation of the report, we have received many helpful comments, suggestions and literature from various treatment firms, equipment suppliers and manufacturers. Recognizing the complexity of the water quality problems and the changing nature of water treatment technologies, the Department of the Environment does not undertake to make, nor does it assume any responsibility for an evaluation of a particular product. It is the responsibility of the individual to make his/her own evaluation and selection.

This report was started by the Nova Scotia Department of the Environment's summer student, Douglas Farrell, in the summer of 1982. It was carried on by Norman McLeod, hydrogeologist with the Department, who completed the report. We wish to express our appreciation to Dr. C. L. Lin, Chief, Water Resources Planning of the Department; Dr. R. McCurdy, Chief, Environmental Chemistry Laboratory, Victoria General Hospital, Halifax; and Mr. James Fraser, hydrogeologist with the Department, for their critical review of the report. To Dave Grantham, Willard D'Eon, and Don Reid, public health engineers with the N.S. Department of Health, our sincere thanks for their helpful comments. We would like to thank Mrs. Ruth Garrison for expertly typing the manuscript.

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INTRODUCTION

The importance of water in today's society cannot be overemphasized. Water is used for drinking, bathing, household and industrial cleaning and for carrying away and diluting waste. Today, each member of the average Canadian family uses 140 to 320 litres (30 to 70 gallons) of water each day. Each trip to the bathroom uses 14 to 23 litres (3 to 5 gallons) of water. Altogether, some 4,546 litres (1,000 gallons) per person per day are needed for manufacturing, industrial, municipal, rural, agricultural, and mining uses.

This booklet details the background of typical well water problems in Nova Scotia areas and presents various remedial measures. Each section of this report includes the cause(s) of the problem, the adverse effects of the problem (on water taste, health, etc.), treatment alternatives, cost estimates of treatment methods, and a suggestion where to get the water analyzed for that particular problem. The treatment methods presented are generally applicable to home water systems. For the sake of completeness, some of the more exotic systems are mentioned. A summary of problems and treatments is presented in Table 2.

In Nova Scotia water utilization is divided equally between surface and groundwater sources. To be useful, water must be available in quantity and quality, at the time and location suitable for the need.A mean annual precipitation of 1300 mm (51 inches) ensures that there is sufficient recharge to groundwater to prevent large fluctuations in well water levels. The actual quantity of water available for withdrawal depends on the depth and diameter of a well and on hydrogeological conditions. The quantity of rainfall recharge is secondary to these factors.

Wells in this province are either shallow dug wells in the unconsolidated overburden or deeper wells drilled into the bedrock. Overburden is predominantly low water-yield glacial till. Because of its low yield, dug wells in groundwater are usually constructed of 90 cm- (3 foot-) diameter crocks with large amounts of storage. Drilled well-yields depend on the type of bedrock (Figure 1), the type of overburden, the depth of the well, and the number of fractures or cracks encountered in the rock while drilling.

In areas where the overburden consists of sand and gravel, saturated with water, construction of screened drilled wells or well points often result in high yield wells with good quality water.

In Nova Scotia, bedrock is generally close to the surface and, commonly, is exposed. The scarcity of overburden often reduces the availability of the natural filtering mechanism of the soil. Once this penetrating water is in the bedrock, there is relatively little filtering action. There is little topographic relief in Nova Scotia. This results in the water table being relatively close to the surface. In addition, sources of groundwater are mostly local.

Because of the close proximity of groundwater to the surface, potentially polluting activities can seldom be situated so they will not interact with the water table. Therefore, groundwater is susceptible to contamination if proper steps are not taken. The efforts required to protect groundwater are usually more effective and cheaper than water treatment methods added to solve a problem. For example, a high nitrate-bacteria problem is most easily dealt with by removing potential sources of pollution, such as manure piles, from the area of the well.

Despite the problems that can occur with groundwater, well water in the province is of good quality. However, there are exceptions. In certain areas of Nova Scotia, mainly due to geologic conditions or areas of culturally-caused pollution, there exists poor quality water requiring treatment (Figure 1). Poor quality water is generally defined as that water which exceeds the Guidelines for Canadian Drinking Water Quality 1978 (Table 1). With these waters, some form of water treatment may be required.

Water is an effective solvent and tends to pick up various chemicals from natural as well as man-made sources. Because of its slow movement and greater travel through earth materials, groundwater or well water has a higher mineral content than surface water. Due to the filtering action of the soil, well water usually has a lower bacterial population and is clearer than surface water.

Water quality problems can be divided into man-made and natural problems. The naturally occurring problems may include excessive

TABLE 1
ABBREVIATED GUIDELINES FOR CANADIAN DRINKING WATER QUALITY 1978

Substance or Parameter	Maximum Acceptable Level, mg/L	Objective, mg/L
Bacteria	*(1) 10 or less total coliforms per 100 ml of water. (2) no coliforms in not more than 10% of samples in 30 day period. (3) no coliforms present in more than 2 consecutive samples from the same site. (4) no fecal coliforms.	
Colour (True colour units)	15 T.C.U.	15 T.C.U.
Odour	---	inoffensive
Taste	---	inoffensive
Turbidity (nephelometric turbidity units)	5 N.T.U.	1 N.T.U.
pH	6.5 - 8.5 pH units	---
Arsenic	*0.05	0.005
Chloride	*250	250
Copper	1.0	1.0
Fluoride	*1.5	1.0
Hardness	500	80 - 100
Hydrogen Sulfide	*0.05	0.05
Iron	0.3	0.05
Lead	*0.05	0.001
Manganese	0.05	0.01
Nitrate (as N)	*10.0	0.001
Sulphate	*500	150
Total Dissolved Solids	500	---
Uranium	**0.1	0.001
Zinc	5.0	5.0

* based on health considerations.

** N.S. Department of Health.

concentrations of iron, manganese, sulphate, chloride, arsenic, uranium, calcium, and magnesium in the well water. The man-made problems include nitrate and bacteria from septic fields and fertilizers; salt from road deicing operations; hydrocarbons from leaking gas and oil tanks; methane, sulphates and chlorides from landfill sites; and pesticides from home, farm or forestry usage (Shawinigan Engineering Ltd., 1980). Some of these chemicals, such as arsenic, pose a potential health hazard. Others, such as iron, may merely be aesthetically displeasing; i.e., they may stain laundry or impart a bad taste to the water. Most of these water quality problems can be reduced by various physical and chemical means, in addition to other alternatives. The decision on the course of action to be taken depends on the type of problem, technical feasibility, alternatives available and, of course, the cost.

TABLE 2
COMMON WATER QUALITY PROBLEMS

Problem	Probable Cause	Corrective Measures	Page
Mineral scale build-up in kettles, water heaters and plumbing Soap scum, excess soap consumption, dingy laundry, bath-tub ring.	Hardness (Hard Water)	(1) Water softeners ..... (2) Phosphate feed	15 16
Red stains on laundry Metallic taste in water Red color to water	Iron	(1) Water softeners ..... (2) Chemical oxidation and filtration ..... (3) Greensand filters	17 18 21
Black stains Red-black water Metallic taste	Manganese	(1) Water softener ..... (2) Iron filters	17 18
Red-brown slime Red filaments Reduced well yield	Iron Bacteria	"Shot" or "Shock" chlori-nation Chlorination filtration units	 20
Gastro-intestinal disease	Bacteria or Virus	(1) Eliminate source (2) Disinfection:- chlorine . - ozone .... - iodination - ultraviolet (3) Well rehabilitation	 9 11 11 12
Corrosive Water	Acid Water (low pH)	(1) Tank type neutralizers .. (2) Chemical feed of an alkaline material ..... (3) Sodium silicate filters . (4) Well rehabilitation	27 27 28
Salty taste, corrosive	Chloride	(1) Reverse osmosis (R.O.) (2) Deionization ..... (3) Distillation ..... (4) Eliminate source (5) Well rehabilitation	30 31 50

TABLE 2 (Cont'd)
COMMON WATER QUALITY PROBLEMS

Problem	Probable Cause	Corrective Measures	Page
Bitter taste, laxative effect	Sulfate	(1) Dealkalization	31
		(2) Distillation	50
Blue hue in infants	Nitrate	(1) Deionization	31
		(2) Distillation	50
		(3) Freezing/thawing	32
		(4) Reverse osmosis	30
		(5) Case well to deeper zone	
Rotten egg smell which disappears if water is left standing	Hydrogen Sulfide (H_2S)	(1) Activated carbon filters	33
		(2) Oxidation - filtration .	34
		(3) Check well venting	
Tastes and Odours	Dissolved organics	(1) Activated carbon	37
		(2) Aeration	39
Cloudy or turbid water	Suspended particles (silt, clay)	(1) Alum treatment	41
		(2) Gravity sedimentation .	42
Neural problems skin lesions, etc.	Arsenic	(1) Arsenic Filter	35
		(2) Distillation	50
		(3) Dug well construction	
Uranium and/or Radioactivity	Uranium, Radon	(1) Construction of a dug well	
		(2) Distillation	50
		(3) Reverse osmosis	30
		(4) Vent well and house ..	43
Hypertension	Sodium	(1) Well Rehabilitation (road salt)	
		(2) Install a 'non-softened' tap for drinking	
		(3) Reverse osmosis	50
		(4) Distillation	50
Gasoline-type odour	Gasoline Fuel oil	(1) Charcoal filters	46
		(2) Reverse osmosis	46
		(3) Aeration	47
Clear tea-like colour	Humic acids	(1) Charcoal filters	49

2. BACTERIAL CONTAMINATION

As defined in the Canadian Drinking Water Guidelines (Table 1) bacterial contamination is when there are more than 10 total coliform bacteria per 100 ml of water (for more details see Table 1). Coliform bacteria are 'indicator bacteria'; coliform are not harmful but may indicate the presence of other disease-causing bacteria or viruses.

As Table 3 illustrates, bacterial contamination of water from sources such as septic fields or manure piles can cause a wide range of infections and disease. However the filtration capability of soil and rock and oxygen-free conditions that exist underground all act to reduce the number of bacteria that move through the ground with groundwater. Accordingly, groundwater is generally a safer drinking water source than surface waters with respect to pathogenic or disease-causing organisms.

The distance that bacteria- and virus-contaminated water can travel in the ground depends on the type of soil or bedrock, the type of water and the type of bacteria. For instance bacteria and viruses may travel one hundred metres in fractured bedrock while the same bacteria may be completely filtered out in thirty meters of saturated porous sand (Crane and Moore, 1984).

The usual cause of bacterial contamination in groundwater is poor well construction. For information on well construction methods see the N.S. Department of the Environment's booklet 'Before You Construct A Water Well'. Dug wells are generally more susceptible to bacterial contamination than are drilled wells. Water supplies derived from surface water and rainwater almost always require disinfection.

Prior to the implementation of any disinfection procedure described in this publication, all reasonable measures to eliminate the problem at the source should be carried out (e.g. well rehabilitation, removal of waste piles, diversion of drainage).

TABLE 3
PATHOGENIC ORGANISMS FOUND IN WATER
AND THE POSSIBLE RESULTING INFECTION/DISEASE [1,2]

Bacteria/Protozoa	Possible Infection/Disease
Escherichia coli (E.coli)	Urinary tract infections, diarrhea in some individuals
Pseudomonas aeruginosa	otitis externa ("swimmers ear" infection)
Salmonella, various types	effects range in severity from typhoid fever, to the common acute intestinal upsets formally known as "ptomaine poisoning"
Klebsiella pneumoniae	may cause a highly fatal type of pneumonia which accounts for 3% of bacteria pneumonia
Bacillus anthracis	causes anthrax in animals which can then be transmitted to humans
Clostridium tetani	if spores introduced into deep wounds during bathing can cause tetanus ("lockjaw")
Vibrio cholerae	cholera, organism may persist for weeks in either very clean or very turbid water
Shigella, various types	acute diarrhea
Yersinia tularensis	gastroenteritis
Francisella tularensis	tularemia, spread via drinking water contaminated by wild animals in rural areas
Entamoeba histolytica	amoebic dysentery - requires fine filtration of water
Glardia lamblia	recurring diarrhea - requires fine filtration of water

1. Ontario Ministry of the Environment, 1981, pp. 107-117.

2. Lehr et al., 1980, pp. 134-137.

In the cases where the above procedures are ineffective or where surface water is the source of supply, disinfection and/or filtration may be required before the water is drinkable. Disinfection involves killing the microorganisms by various means.

2.1 Chlorination

Chlorination is the most common method of disinfection. There are two types of chlorination, 'shock' or 'shot' chlorination and continuous chlorination.

Shot chlorination involves the manual addition of a quantity of chlorine to a well (i.e., a bottle or two of Javex) to eliminate a temporary bacterial contamination problem. Shot chlorination is described further in Appendix C.

Continuous chlorination involves the continuous addition of a small quantity of chlorine to the water system. It is used to disinfect a source of water, such as lake water, which may at any time contain disease-causing bacteria.

2.1.1 Types of Chlorinators

There are 3 major types of chlorinator units used for the continuous addition of chlorine:

(1) The "pump type", positive displacement or "P.D." feeder, is an electrically powered unit that operates by alternately expanding and compressing a rubber device (like a plunger) or by moving a piston (like a syringe). The equipment is adjustable during operation and is especially desirable where water pressure is low or fluctuating (Figures 2 and 3).

(2) Eductor-type chlorinators use the natural vacuum created by the flow of water in a pipe to draw the chlorine solution from the disinfectant reservoir. The two most common types of eductor feeders are aspirator and suction feeders.

Aspirator feeders utilize the vacuum created by the water flowing perpendicular to a nozzle. The vacuum draws the chlorine solution from a container into the chlorinator unit where it is mixed with water passing

through the unit. The solution is then injected into the water system (Figure 4).

Suction type feeders have a single line that runs from the chlorine solution through the chlorinator unit and connects to the suction side of the pump. The solution is pulled from the container by suction created by the pump.

(3) Tablet hypochlorinators (Figures 5 and 6) consist of a special pot feeder containing calcium hypochlorite tablets. Small jets of feedwater are injected into the lower portion of the hypochlorite bed. Dissolution provides a continuous source of fresh hypochlorite solution. The unit does not require electricity and can operate where water pressure is low.

The three types of units mentioned; P.D., eductor and tablet hypochlorinators are all quite effective and are roughly the same cost (approximately $550*). Choice of a suitable unit is a matter of personal preference as to the exactness of dosage, degree of maintenance, pressure and rate of water use.

2.1.2 Advantages and Disadvantages of Chlorination

On the positive side, chlorine is a highly effective disinfecting agent. It is relatively safe and inexpensive.

On the negative side, chlorine may combine with certain organic particles in the water to form suspected cancer causing chemicals (Lehr et al, 1980, p.148). Insufficient quantities of chlorine may allow the survival of some disease-causing bacteria whereas too much chlorine may impart a bad taste and odour to the water. This means that care must be taken in adjustment of the feeders. Cloudy water may reduce the effectiveness of chlorinators. Variation in water quality may affect the degree of protection given by a specific pre-set dosage of chlorine. Feeder units require varying degrees of maintenance depending upon the type.

*-The estimated costs are based on 1984 prices.

2.2 Ozonation

Ozonation occurs when ozone gas (O_3) is drawn into the water to kill bacteria. Ozone is quite a popular disinfectant. However, it is not used as extensively in North America as in Europe. Local "spring water" distributors favour ozone because it leaves no taste or odour in the water. Ozone is actually more effective against bacteria and viruses than is chlorine. It also may reduce iron, manganese and lead content of the water by oxidation and is not affected by pH, temperature or ammonia. Ozonation must occur at the point of use. The disadvantages of ozonation include:

1. Higher operating costs than chlorination.
2. Unreliable equipment requiring frequent repair and varied maintenance.
3. No lingering bacteria-killing ability as there is with the use of chlorine.
4. Production of many by-products which have undetermined effects on human health.

These units are available in Nova Scotia from distributors at an average cost of about $2,500 for a unit capable of treating a residential supply.

2.3 Iodination

Iodination is another treatment method available for disinfection. Iodine has been used as an antiseptic and a biocide for over 100 years. Disinfection is achieved by adding a controlled amount of a saturated iodine solution to water. The iodine can be added by means of a chemical feed pump or an iodination cartridge. The latter requires no electricity and may last five years for a family of four. Generally, a cartridge filter is required before iodination to protect the unit from sediments.

Approximately 1 mg/L of iodine is added to the water. Use of iodine gives the water a residual bacteriocidal activity that will kill off any bacteria in the plumbing system. Apparently iodine does not give

the water any objectionable taste or odour at proper treatment levels. Iodine is effective in the pH range 5-9.

Water with a high organic content may use too much iodine thus preventing the use of iodine for disinfection. Persons with thyroid conditions who should not consume iodine, can have a charcoal filter installed to remove the iodine before consumption.

2.4 Ultraviolet Irradiation

Ultraviolet water-disinfection systems use the same killing action on bacteria as sunlight. The germicidal activity depends on the intensity of the lamp and the length of exposure and it occurs in a fraction of a second.

The system consists of one or more ultraviolet lamps in a quartz sleeve. Water is directed past the lamp in a relatively thin layer so that all of the bacteria in the water is exposed. It is important that the water is clear so that none of the bacteria escapes irradiation by being in the shadow of particles. Accordingly a filter is usually installed before the lamp to remove dirt, rust and hydrogen sulfide.

The systems are automatic, use no chemicals and produce no by-products that cause tastes or odours. Unlike chlorination systems, the ultraviolet lamps have no residual germicidal activity. Therefore, the plumbing system should be periodically cleaned and disinfected. The lamp is run continuously and it will last about a year. It consumes 40-90 watts of power. The ultraviolet system sells for $300-$700. Replacement cells cost $50-$170.

2.5 Bacteria Monitoring

Testing for bacteria can only be done in a laboratory with microbiology facilities. There is no simple test kit as there is for many other problems. In Nova Scotia, the coliform group of microorganisms are the commonly used bacteriological indicators of water quality. Fecal coliforms characteristically occur in the intestines and feces of warm

blooded animals. The presence of these organisms indicates the potential presence of disease-causing bacteria at the source. Any water supply that is being continuously disinfected should be monitored to ensure that all bacteria are being killed. The Nova Scotia Department of Health will perform two free tests per year on an individual water supply.

A typical test for these organisms involves growing them in a particular medium, in a number of test tubes or petri plates. The production of gas or growth of colonies is monitored to determine the presence and concentration of organisms.

The Guidelines for Canadian Drinking Water Quality 1978 (Table 1) state that:

1. No sample should contain more than 10 total coliform organisms per 100 millilitres.
2. Not more than 10 percent of the samples taken in a 30 day period should show the presence of coliform organisms.
3. Not more than 2 consecutive samples from the same site should show the presence of coliform organisms.
4. None of the coliforms detected should be fecal coliforms.

The bacterial rating of drinking water is illustrated in Table 4. Note that the information on Table 4 is from Ontario. Interpretation of the bacterial rating may vary slightly in Nova Scotia.

TABLE 4

INTERPRETATION OF COLIFORM COUNTS*

Coliform bacteria per 100 mL		Interpretation
Total	Fecal	
160	60	Unsafe for drinking. This water is contaminated and should not be used for drinking under any circumstances. Do not attempt to apply these standards and interpretations to surface waters used for swimming.
10-160	1-60	Unsafe for drinking. Pollution source may be some distance from the water source, or diluted with large volumes of pure water, or the sample may not have been received within 48 hours of being taken. Samples older than 48 hours cannot provide reliable results.
10-160	0	Unsafe for drinking. Contamination is not likely to be of sewage origin unless far removed from the water source or unless there has been a delay in receipt of sample. Common with new wells before disinfection and shallow dug wells which are not properly sealed.
1-9	0	Doubtful for a single sample, but safe for drinking if condition remains stable and supply is protected and located at least 100 ft. from any source of human or animal wastes. Repeat samples may not show exactly the same results because bacteria are not distributed uniformly in water, contamination tends to enter intermittently and numbers can change during sample transit time. Frequent sampling recommended.
0	0	Safe for drinking
Est		Unsafe for drinking. Number has been estimated due to some interference with the test. Exact number is not really critical, especially if in excess of limits shown above, for judging safety.
O/G		Doubtful condition and not recommended for drinking. No coliform bacteria could be detected because of "overgrowth" by other bacteria. This condition frequently occurs with new wells, dug wells receiving soil drainage, or wells which have been idle for sometime. Collect another sample and identify clearly "REPEAT SAMPLE".

*Ontario Ministry of the Environment, 1980

3. HARD WATER

Hardness in water is commonly defined as the inability of the water to form soap lather. Actual hardness is determined by the calcium and magnesium content of the water as $CaCO_3$. These elements dissolve as water flows through certain rock units such as limestone, dolomite and gypsum.

"Hard" water leads to technical and economic problems. It can cause scale to form on kettles and boilers, prevent soap from lathering and give a dingy appearance to laundry. High concentrations are not known to pose a health hazard. In fact hard water may have a protective effect.

In Canada, acceptable hardness can range as high as 80 and 100 milligrams per litre of water. Many treatment companies refer to the older, English units of measurement such as grains per gallon. Five to six grains per gallon (gpg) is considered acceptable and is equivalent to 80 to 100 milligrams per litre (mg/L). Grains per gallon can be converted to milligrams per litre by multiplying the gpg figure by 17.2. Water with a hardness concentration of 200 mg/L (12 gpg) is considered undesirable and water having 500 mg/L (30 gpg) is considered unsuitable for domestic use.

The units designed for treatment of hardness are called water softeners. There are two major types. The first type removes calcium and magnesium by exchanging them for sodium atoms. Water flows through an exchange resin charged with sodium. Calcium and magnesium in the water are traded for sodium. Once the resin becomes saturated with calcium and magnesium it can be regenerated by backwashing brine. These softening units increase the sodium content of the water. Persons with heart trouble or high blood pressure should consult their doctor before drinking water softened by this method.Figure 7 illustrates a typical ion-exchange softener.

Only the water to be heated and cold water used for laundry and washing purposes need be softened. Flush toilets use a large amount of

water and a considerable saving can be realized by not softening this water. A tap for cold unsoftened water may be installed for drinking purposes in the kitchen.

The size of unit to be used is determined by (a) the amount of water used, (b) the hardness of the water, and (c) the frequency of brine regeneration.

The cost of a unit depends upon its size. A unit treating 20 gpg (342 mg/L) hardness at an 8 gpm (30 litres/min) output costs between $700 and $800. A unit capable of treating 60 gpg (1026 mg/L) hardness at a 10 gpm (40 L/min) output costs between $1100 and $1400. Softeners of this type are available from most local water treatment retailers (see Appendix A for list of current retailers).

Water softeners will also reduce iron and manganese. On the negative side, adding sodium to the water (as mentioned previously) may make the water more corrosive which may lead to pipe and fixture corrosion. Water softeners alone are therefore not desirable for those waters which are naturally corrosive.

The alternate method of treatment is hardness-complexation with the use of phosphate additives. Chemicals such as sodium hexametaphosphate are added to the water by a chemical feeder. These chemicals prevent hard water from reacting with soap to form a scum. Scale still forms in kettles and boilers however.

A chemical feed pump (about $800) such as is used for chlorine, can be used. This is a positive displacement pump that injects chemical only when the well pump is running. Pot feeders are installed on the inlet supply line and a portion of the water is passed through a canister containing slowly dissolving phosphate crystals.

4. IRON

In Nova Scotia, iron concentrations in groundwater generally range from 0.01 to 10.0 mg/L. Iron concentrations greater than the recommended limit of 0.3 mg/L (Table 1) may stain sinks (red-yellow), discolour laundry, and impart a bitter or metallic taste to beverages (especially coffee or tea). Iron in water is not considered a health problem. The treatment systems to remove iron include conventional water softeners, followed by filtration and/or settling and chemical-oxidation filters such as greensand filters.

4.1 Water Softeners to Remove Iron

Of the treatment systems available, water softeners are the least expensive. They are capable of removing up to 4.0 mg/L of iron. If the water to be treated is of low hardness, the use of water softeners will make the water more corrosive and reduce the concentration of beneficial elements such as calcium and magnesium. The concentration of sodium in the water will be increased through use of a softener.

To use a softener to effectively remove iron, the water should be clear when drawn, have a pH no less than 7.0 and be free of iron bacteria (see Table 5). A softener will remove iron when the pH of water is less than 7.0. However, the lower the pH, the less effective the method.

Iron in softeners can cause a problem if it oxidizes and coats the resin bed. To prevent this, the softener can be set to regenerate more frequently at a lower salt dosage to decrease the chance of iron oxidation. Alternatively, salt can be used with an additive to redissolve any iron that has oxidized. Should the resin bed become iron-fouled, it can be cleaned with a resin cleaner such as sodium hydrosulfite ($Na_2S_2O_4$). Some of the resin cleaners available include 'Iron-out', 'Iron-free' and 'Rover'. Costs range from $8.00 for a 12 oz. bottle to $11.00 for a 16 oz. bottle.

4.2 Oxidation-Filtration Methods

The oxidation method involves the conversion of dissolved iron to fine iron particles which are more amenable to filtration. This conversion process is called 'oxidation'. Contrary to what one might think, oxidation does not necessarily involve oxygen. The oxidation of dissolved iron can be accomplished with oxygen, chlorine, chlorine dioxide, ozone and potassium permanganate. Chlorine and potassium permanganate are used most frequently.

Oxidation-followed-by-filtration methods are usually used on water with high concentrations of iron, i.e., greater than 4.0 mg/L. As a rule of thumb, iron filters can be used on waters which have an alkalinity of at least two-thirds of the total dissolved solids concentration and a pH of 7 or higher. While some manufacturers claim effectiveness at a pH as low as 6.5, higher ranges promote better 'rust' formation and filtration (Lehr et al, 1980).

It should be noted that the units that use oxidation-filtration have a 10-15% iron bleed (i.e., iron lost) and, if iron concentrations are high enough, a water softener will be required to remove any iron that 'bleeds' through the filter.

TABLE 5
SELECTION OF IRON-REMOVAL METHOD*

Iron level mg/L	Bacteria	Clear or red when drawn	pH	Method
0-5	No	Clear	6.0-7.0 +	Softening
0-5	Yes	Clear	7.0 +	Shot-chlorination Oxidizing filter
5-20	No	Clear	7.0 +	Oxidizing filter
5-20	Yes	Clear or red	7.0 +	Shot-chlorination Continuous chlorination Oxidizing filters
0-20	No	Red	7.0 +	Oxidizing filter
20-30	No	Clear or red	7.0 +	Continuous chlorination Oxidizing filter Clarifying filter
0-25	No	Clear or red	5.6-8.0	Oxidation by aeration/filter

*Adapted from Lehr et al., 1980, p.177

4.2.1 Oxidation by Chlorine

Chlorine is a popular treatment because chlorine can convert dissolved iron to iron particles and can kill iron bacteria as well. The rate of chlorine feed can be varied depending on the degree of iron problem. Quite simply, the iron is oxidized by the chlorine and the resulting oxidized iron or iron particles are subsequently removed by a filter. This method is usually accomplished by injecting chlorine into the inlet of a pressure or storage tank. The chlorine causes iron particles or rust to form in the tank where it can be removed by a filter. The chlorine feed-pump injects chlorine only when the pump is running. A tank 10 times the size of the system flow rate (gpm or litres/min) will usually provide adequate contact time.

An additional benefit of this type of oxidation-filtration is its ability to control iron bacteria. There are several types of iron bacteria common to well water supplies. These bacteria use iron as food. The bacteria deposit the used iron in "sheaths" of gelatinous matter which forms a red sludge or slime. This sludge or slime accumulates where water is allowed to stand for periods of time such as flush tanks, pressure tanks or humidifiers. Periodic "shock" or "shot" chlorination of the well is also often used to solve this problem (Appendix C). Severe cases may require extremely high doses of chlorine and flushing of the entire system.

4.2.2 Iron Oxidation by Air

An iron removal unit has been developed that makes use of air to oxidize the iron to iron particles. The iron particles are then removed by a filter containing an oppositely charged medium. The unit is capable of backwashing the iron out of the filter media.

The unit is effective in the pH range 5.6 to 8.0 and can remove up to 25 mg/L of iron. This is four times the capacity of a greensand filter. No chemicals are used.

The main disadvantage to the unit is that it requires a minimum flow of 23 L/M (5 gpm). This is higher than the yield of many of the

wells in Nova Scotia. Organic contaminants such as tannin and other humic acids will prevent the iron particles from being removed by the filter.

The iron-aeration removal unit sells for about $1000.

4.2.3 Iron Oxidation by Potassium Permanganate

Chemical oxidation using potassium permanganate ($KMnO_4$) is an alternative to chlorine oxidation. Potassium permanganate causes the dissolved iron to form iron particles faster than chlorine. It also does not give the water the 'chlorine smell' that use of chlorine does. Potassium permanganate is not as pH dependent as chlorine. The decision to use potassium permanganate or chlorine as oxidant depends upon the individual water supply and system, the contaminants to be removed, the cost and availability of chemicals, and the tendency of the water to develop a chlorine-type odour.

4.3 Greensand Filters

Greensand is essentially a filter and an oxidant combined. The filter (sand) has the oxidant (manganese dioxide) coated onto the grains of sand. When water containing iron (and manganese) is passed through this material, the manganese dioxide on the sand causes the iron (and manganese) to come out of the water and coat onto the greensand. After the greensand is coated with iron it is regenerated with potassium permanganate. The pH of the incoming water must be 7.0 or greater to prevent the dissolution of the manganese dioxide.

A modification to this process is available whereby the manganese dioxide is continuously regenerated with potassium permanganate. Potassium permanganate is continuously fed to the water before entering the filter. The iron and manganese are oxidized by the potassium permanganate so that they form particles which are caught up by the filter. If too little potassium permanganate is added, the untreated iron and manganese remaining in the water coats onto the greensand; if too much potassium permanganate is added, the greensand is regenerated. Thus, uniform amounts of potassium permanganate may be added to a water

containing varying concentrations of iron and manganese.

4.4 Extremely High Iron Concentrations

If the iron concentration is extremely high and must be treated (i.e. another well location cannot be found) then a combination of systems may be required.

4.5 Conclusions

In Nova Scotia, where the iron concentration in groundwater generally does not exceed 5 mg/L, a water softener is often the most effective and least expensive treatment. Iron removal units also remove manganese.

A greensand filter alone should cost beween $850 and $950 at 1984 prices. Chemical-oxidation-filtration would require the purchase of a chemical feed pump and a filter(s) for $1000 - $2000 for the set.

Iron treatment units can be purchased locally under several brand names (see yellow pages under Water Treatment and also see Appendix A). Analysis of water for iron can be made by any of the laboratories listed in Appendix B. Once the concentration (mg/L) of iron (Table 5) and chemical character of the water is determined, the proper treatment unit(s) can be applied.

5. MANGANESE

Manganese concentrations in excess of the recommended limit of 0.05 mg/L can cause grey to black staining on porcelain and pots and pans. It is not a health hazard at the concentrations normally encountered in drinking waters. In some waters in Nova Scotia manganese concentrations in well waters may reach 4.5 mg/L.

Generally, treatment methods which remove manganese also remove iron (see Chapter 4). Water softeners can remove manganese concentrations of up to 2 mg/L. Greensand filters and oxidation-filtration can remove concentrations over 2 mg/L in a manner similar to iron removal.

Before purchasing a unit for manganese removal an expert should be consulted to determine the most appropriate treatment method. If a water softener is used, care should be taken to prevent resin fouling (see Section 4.1). The prices of units are the same as those for iron removal units.

6. ACID WATER

Acidity is commonly expressed in pH units (although technically speaking this is not entirely correct). The pH scale ranges from 0, which is extremely acid, to 14 which is extremely basic (caustic; alkaline). A pH of 7.0 is neutral. The average pH of groundwater in Nova Scotia is about 6.5, i.e., slightly acid. The pH values for various substances are shown on Table 6.

Acidic water is frequently, but not necessarily, corrosive. Some of the factors influencing corrosion include the dissolved oxygen content, the mineral content, the temperature, the catalysts present and the pH of the water. For instance, salt water is corrosive yet may not be acidic. Acidity is considered to be the most important factor causing corrosion solely because it is easily controlled. In fact, neutralizing water may slow down corrosion but in all likelihood it will still occur.

Low pH water may stimulate corrosion of plumbing. This can be indicated by elevated iron, lead, copper and/or zinc concentrations in the water. Road salt, seawater, swamp water and acid mine drainage can also cause well water to become more corrosive. Treatment methods usually neutralize the pH of the water. They do not eliminate corrosion caused by salt or swamp water.

Acid water seems to be a problem more common to dug wells than drilled wells. Shallow well water and surface water have had little opportunity for neutralization by geologic materials.

There are two types of units that deal with acid water:

1. Tank-type neutralizing filters.
2. Chemical feed pumps supplying a caustic (basic) material such as soda ash.

It should be noted that any pH adjustment of acid water may cause iron and manganese to 'come out' of the water and clog the filter, well, or plumbing system.

TABLE 6
AVERAGE pH OF VARIOUS SUBSTANCES

Substance	Average pH
Groundwater (N.S.)	6.5
Vinegar	2.4-3.4
Beer	4.0-5.0
Soft Drinks	2.0-4.0
Milk	6.3-6.6
Household Bleach	10.0
Rain Water	3.8-6.0

6.1 Tank-Type Neutralizing Filters

The tank-type neutralizing filter uses a mode of operation similar to chemical reactions which occur in nature. The filter-medium is crushed limestone, magnesia, or both. When the acid water passes through the filter, it dissolves some of the limestone present in the filter. Thus the water is hardened somewhat through the neutralization process.

The filters are not very effective on pH's lower than 6.0. A limestone filter, on average, will raise the pH of the water by approximately one pH unit. Magnesia filters can raise the pH higher, depending on the water composition.

The limestone bedding can cause pressure loss across the filter. Also the flow rate must often be restricted to ensure adequate neutralization. In addition to this, because it makes use of a dissolving medium, it will be necessary to periodically replace the filter bed.

Tank-type units sell for approximately $1500.

6.2 Chemical Feed Pumps

A chemical feed pump using soda ash (sodium carbonate), calcium hydroxide or sodium hydroxide can treat water with a pH of 4.0 to 6.8. It involves a simple acid-base neutralization which requires a minimum of contact time. The alkali can often be injected directly into the well preventing any part of the plumbing system from contacting the corrosive water.

Neutralization by this method requires the handling of dangerous caustic solutions. Typically soda ash is mixed at a ratio of 1-2 kg (2-4 lb.) per 15 litres (4 gal.). It is fed at a rate sufficient to raise the pH to 7.0 at the faucet farthest from the installation. This necessitates some manual adjustments to the feed rate.

To neutralize water with pH below 4.0 sodium hydroxide is added by a chemical feed pump. It is mixed at the same concentration and injected in the same way as soda ash.

Both of these chemical feed injection methods are relatively inexpensive and easy to maintain. Maintenance involves keeping the solution tank full and adjusting the feeder by trial and error to achieve a desirable pH of about 7.0. pH can be measured with a pH meter available at any laboratory equipment retailer or with chemical indicators which change colour with pH. Chemical indicators (i.e. litmus paper) are available from water treatment companies and tropical fish stores.

6.3 Caustic Waters

For scale forming, extremely high pH waters, sulfuric acid can be added via a chemical feeder instead of sodium hydroxide. This is another neutralization type of reaction and the same rules of operation apply as for acid water.

6.4 Sodium Silicate

In municipal systems a popular treatment for corrosion control is the use of sodium silicate. Unlike the aforementioned methods, no neutralization of acids is involved. The idea is that the silica will form a film on the piping to protect the plumbing from corrosion. The treatment must be relatively continuous, and effectiveness is favoured by high water velocity and generally lower pH values (American Water Works Association, 1971).

Treatment systems available locally consist of simple in-line filter cartridges containing sodium silicate amongst other treatment media such as activated carbon. The manufacturers claim that these units "inhibit scale build-up and corrosion". While water is sitting in the filter, sodium silicate will slowly dissolve into the water. When the water system is used, the dissolved sodium silicate will leave the filter

and presumably coat the inside of the piping. Note that criteria for effectiveness mentioned above, 'relatively continuous' is not met with the filter as described.

These filters sell for approximately $110.

7. CHLORIDE, SULPHATE, AND NITRATE

The recommended limits for chloride, sulphate, and nitrate in drinking water in Canada are 250 mg/L, 500 mg/L and 45 mg/L (10 mg/L nitrogen) respectively. High chloride concentrations often mean high sodium concentrations, a potential concern for persons with high blood pressure or heart trouble. Chlorides are responsible for the salty taste in water. Sulphate imparts a bitter taste to the water and may cause a laxative effect to a new consumer. Nitrate is often indicative of contamination from such sources as septic fields, fertilizers, and manure piles. Levels in excess may cause methemoglobinemia or 'blue-baby' in infants (a condition where the red blood cells do not carry enough oxygen) whereby the child becomes listless and the skin takes on a blue hue.

There are four major types of treatment methods to remove these chemicals: reverse osmosis, dealkalization, deionization, and distillation. Distillation is discussed in Section 15.2.

7.1 Reverse Osmosis

Reverse osmosis involves passing mineralized water under pressure through a semi-permeable membrane. This membrane allows fresh water to pass through the membrane while leaving many of the minerals behind.

There are many types of reverse osmosis membranes with nylon and cellulose acetate being the most common. The membranes are highly susceptible to build-up of calcium or sulphate compounds on the membrane. Some species of bacteria may feed on the membrane requiring the use of chlorine or ozonation to kill the bacteria before they reach the unit. Then some treatment may be required to remove the chlorine or oxygen. Iron may also clog the membrane.

Generally iron and hardness should be removed by treatment with a softener or some other method before the water reaches the reverse osmosis membrane. Hardness can be tolerated if the unit is set up so that

the membrane is periodically washed with a mild acid. At the very minimum there is a paper dirt/rust filter before the unit and a charcoal filter after the unit.

As shown in Figure 8, water is forced against a membrane in the unit (Figure 8). This part of the module retains the solids and, to prevent clogging, must be constantly washed to waste by the incoming water supply. It is estimated that for every litre of water produced, four litres go to waste. An average unit produces about five gallons of water per day and fits under the sink. The efficiency of the unit with respect to the production of water is temperature dependent. At 25^{o}C reverse osmosis units are most efficient. The effectiveness of the unit in removing the minerals of concern can vary from 50 to 90% depending on the quality of the water being fed into the unit.

A typical reverse osmosis setup is illustrated in Figure 9. The cost of the units available in Nova Scotia are in the $500 to $800 range. The membrane ($60-$70) is usually changed once a year. The cost of the pretreatment systems mentioned previously depends on the quality of the input water and the type of pretreatment required.

7.2 Dealkalization

A dealkalizer or anion exchange system is designed to remove the sulphates. This works on the same principle as a water softener, the sulphates are exchanged for chlorides using a modified resin. The unit therefore increases the total chloride concentration. If chloride is already a problem this unit is not recommended.

7.3 Deionization

Deionization or demineralization is designed to remove all of the minerals from water. It operates like a water softener except there are two types of resins, one to remove positively-charged minerals (cations) and another to remove negatively-charged minerals (anions). These units are relatively expensive ($2,000-$3,000).

The use of ion exchange systems for demineralization should only be considered for treatment of water with less than 2000 mg/L TDS (total dissolved solids) concentrations. These units are quite efficient and, mechanically, simple to operate. Disadvantages include maintenance such as regenerating the resin, and disposal of the waste brine solutions and a resulting flat-tasting, very soft water lacking many beneficial minerals.

7.4 Nitrate Removal by Freezing/Thawing

Research by Rowe (1983) and McCurdy (pers. comm., 1985) has found that nitrates can be separated from water by freezing the water. When 70% of the water is frozen, approximately 90% of the nitrate is concentrated in the remaining 30% of liquid water. This water is then poured to waste and the ice is thawed for consumption. The result is a water that contains 90% less nitrate than it did originally.

8. HYDROGEN SULFIDE

Hydrogen sulfide gas (H_2S) is a byproduct of bacterial activity. It is produced when microorganisms degrade sulfur-containing materials in environments devoid of free oxygen. These microorganisms release sulfide in a manner similar to how human beings release carbon dioxide. This problem is common in Nova Scotia and is easily identified by a characteristic rotten egg odour. A fine black material may be present due to the reaction of H_2S with metals in the water. In addition to the odour problem, this material can cause a black stain on laundry, silverware and fixtures. The problem can often be corrected by ensuring that oxygen is abundant in the well. This can be accomplished by using vents on the well which allow air to contact the water. If the problem persists water treatment options are available. These include activated carbon filters, oxidizing filters and oxidation-filtration.

8.1 Activated Carbon Filtration

Activated carbon or charcoal filters are effective for low levels of H_2S (less than 1 mg/L). The gas is absorbed by the carbon filter until the filter is saturated, at which time the charcoal requires replacement. The actual unit resembles an iron filter, but the filter bed cannot be backwashed or otherwise reused when it is used for H_2S removal. The carbon will absorb more than just the H_2S gas. Accordingly, the filter's life can be shortened by other less obnoxious impurities such as iron.

The cost of a unit is quite variable. A small faucet-attached unit might cost $40-60 while a larger cartridge-type might cost between $200 and $300. A unit for treatment of all the water used by a home may cost $1000 with a $75 cost for periodic bed replacement.

8.2 Oxidizing Filters

Oxidizing filters cause H_2S to form sulphates which have no odour. Potassium permanganate or chlorine added to the water with a chemical feed pump can cause oxidation to occur. A filter is usually required after the addition of the potassium permanganate or chlorine to pick up whatever other minerals (i.e., iron and manganese) that have come out of the water because of the oxidation. Frequently a greensand filter is recommended. This unit can then correct the odour problem and also remove iron and manganese.

Prices of these filters are similar to those for iron filters of similar design.

9. ARSENIC

Arsenic occurs naturally in many rocks, minerals, and soils. In Nova Scotia, there are several areas with high arsenic concentrations in the rocks, especially those associated with a gold-bearing series of rocks.

Arsenic is a cumulative toxin affecting the nervous system. The recommended limit for arsenic in drinking water in Canada is 0.05 ppm (mg/L).

Until recently, the only solution to an arsenic problem has been to find an alternate source of water. There are now several treatment units available to remove arsenic from water. One such unit was developed by the Nova Scotia Research Foundation Corporation and is being marketed by P & H Enterprises Ltd., General Contracting. The unit sells for approximately $1500.

The operation of this arsenic unit (Figures 10 and 11) is much the same as that of a greensand filter. Arsenic-bearing water is passed through a chlorination unit and then through a bed of ferric hydroxide which causes the arsenic to coat onto the bed. The ferric hydroxide can cause this 'coating' to occur over the pH range of most groundwaters and requires a contact time of one minute.

Reductions in arsenic concentration as high as 99.9% have been realized. Beds 43 X 25 centimetres (19 X 10 inches) are capable of treating 360,000 litres (79,200 gallons) of water containing 0.25 mg/L arsenic. It has been shown to reduce arsenic concentration to less than 0.01 mg/L. When used at a rate of 23 litres (5 gallons) per day to supply only cooking and drinking water, these units are expected to have a theoretical life of 40 years.

A second treatment unit designed for the removal of arsenic from drinking water is also available. The system is comprised of two disposable activated alumina cartridges connected to a separate cold water faucet and is usually installed on the kitchen sink. The cost of the

system is approximately $600.00. The life span of the cartridges is 1.5 to 2.0 years depending upon the concentration of arsenic to be treated, the amount of water used and the pH.. The cost of cartridge replacement is in the range of $80.00 to $90.00. Tests to date of this system indicate that reductions of arsenic from 0.13 - 0.16 mg/L to less than 0.005 mg/L have been achieved. This represents a reduction of greater than 97 percent.

Reverse osmosis has also been found effective in the removal of arsenic from water supplies. Tests conducted by the N.S. Department of Health indicate that R.O. units can reduce arsenic concentrations of up to 1.2 mg/L to below 0.005 mg/L representing a 99.6 percent removal efficiency. Reverse osmosis units by themselves sell for $500-800. However, pretreatment is frequently required (i.e., softening) which raises the cost of this method of treatment (Section 7.1).

Arsenic can also be removed with a distillation unit (Section 15.2).

Analysis for arsenic can be carried out at one of the chemical laboratories listed in Appendix B.

10. ODOUR AND TASTE

Taste-and-odour-causing substances include: methane, hydrogen sulfide, industrial wastes, pesticides, decaying plant and animal matter, gasoline, oil, residual chlorine, and by-products of chlorination. Often, these materials are present at levels which are undetectable by instruments or analytical methods but are detectable by human senses (Table 7).

The solution to the odour/taste problem depends, to some extent, on the source of the problem. For instance, gasoline and oil do not readily decompose in the ground. They can travel long distances and remain in the soil for a long period of time. The best solution for this type of problem is to remove the soils containing the gas or oil, eliminate the source and install an activated carbon filter until the oil or gasoline can no longer be detected. Of course, an alternate water supply is also another option in this instance.

10.1 Activated Carbon Filters

Activated carbon or charcoal filters can remove low concentrations of tastes and odours from a wide variety of sources. The activated carbon "absorbs" the offending chemicals onto its surface (see also Section 8.1).

There are two major types of activated carbon filters; cartridge type and bed type. Cartridge type are easily installed directly on a faucet. Once they have used up their filtering capacity, the entire cartridge is replaced. There are also larger, under-the-sink cartridges available which can be backwashed to remove heavier solids buildup (Figure 12).

Bed-type carbon filters are designed to treat most of the water being used in a home. This type of unit is usually placed beyond the chlorinator and/or the water softener. The unit can be backwashed periodically to remove suspended dirt. The frequency of backwash depends

TABLE 7

ODOUR AND TASTE CHARACTERISTICS OF COMMON INORGANIC CHEMICAL CONSTITUENTS FOUND IN WATER*

Chemical	Taste or odour characteristics in water
Iron	Bitter taste
	Metallic taste
Manganese	Bitter taste
Sulfate	Bitter taste
Hydrogen sulfide	Rotten-egg odour
Sodium chloride	Salty taste
Bicarbonates	Flat, soda taste
High TDS content	Salty taste

*Lehr et al, 1980, p. 111

upon the rate of use and the manufacturer. For an average household an activated carbon unit will last 1 to 3 years depending on quantity of water processed and the intensity of taste and odour (Figure 13).

10.2 Oxidation Chlorination

Chlorination is somewhat effective in the elimination of odours because it changes some chemicals that cause odours and it eliminates bacteria. Oxidizing agents such as chlorine, potassium permanganate and ozone cause offending substances to form particles after which, they can be filtered out.

10.3 Aeration

Aeration removes tastes and odours when the responsible agent is a gas such as hydrogen sulfide or methane. This technique involves exposing the water to air by means of turbulence or "bubbling" of the water. Well water hydrogen sulfide odour may be eliminated by ensuring the well vent is clear allowing oxygen access to the water.

Units designed to remove odour and taste are available locally. Small activated charcoal units are available at any of the firms listed in Appendix A. They are also available in many hardware and department stores.

11. CLOUDY WATER

Turbid or cloudy water is caused by the suspension of particles in the water. The Canadian Drinking Water Guidelines (Table 1) have set five nephelometric turbidity units (NTU) as the maximum acceptable level with an objective level of less than one NTU. This limit has been established on the basis of both health and aesthetic considerations. Turbidity in excess of 5 NTU may result in a noticeable cloudiness in the water and, consequently, may be considered objectionable. High levels of turbidity can also protect micro-organisms from the effects of disinfection and stimulate the growth of bacteria.

Turbidity is a common problem in surface water supplies where erosion affects a watercourse, in dug wells receiving water from the surface and in drilled wells constructed in soft bedrock. A leaking well casing may also cause the problem.

There are three major methods for alleviating a turbidity problem: coagulation, sedimentation, and filtration.

11.1 Coagulation

Coagulation is a process by which fine suspended particles collect into large particles that settle to the bottom. The process is started by adding to the water a chemical such as alum which causes suspended particles to combine and form larger particles. Factors affecting the coagulation rate include pH, water temperature, particle size, rate of water-coagulant mixing and the ultimate quantity of coagulant used.

Other coagulants include ferric chloride and ferric sulfate. When the pH ranges between 6.8 and 7.5 alum is recommended. If the pH is 5.5-8.8 ferric sulfate can be used.

11.2 Sedimentation

Sedimentation involves letting the water stand still while gravity causes the larger particles to settle out. It can be accomplished in a quiet pond or a properly constructed tank or basin. For a significant reduction in suspended matter the detention time must be at least 24 hours.

The inlet to the sedimentation tank should be designed so the incoming water is distributed across the entire width of the tank. The outlet should be located at the opposite end of the tank. Baffles can be used to reduce short circuiting of water and high local velocities. The system should be designed with two separate sections to facilitate cleaning and repair. The frequency of cleaning will depend on the size of the tank, the turbidity and the water usage rate.

11.3 Filtration

Filtration is the process of removing suspended matter from water as it passed through beds of porous material. Filters filled with sand or diatomaceous earth can be purchased as cartridges which can be added to water lines.

Details on the above methods can be obtained from the dealers listed in Appendix A. Prices vary with sedimentation being the least expensive, and filtration being the most expensive.

12. URANIUM

Uranium is widely distributed and is present in a variety of minerals. In Nova Scotia excess uranium may be found in well water depending on the source rock and groundwater movement in a number of areas and in varying rock units. On the Halifax peninsula (Hatchet Lake, Harrietsfield, St. Margarets Bay) it is found in granite. In the Tatamagouche-Pugwash area uranium is found in mudstones and conglomerates. Uranium has also been found in groundwater in New Ross, Hubbards and Vaughan and in contact areas between granite and slates.

Uranium is usually found in drilled wells, penetrating thick deposits of glacial overburden, especially in granite areas. At present the only solutions to excessive uranium in water are construction of a dug well, installation of a distillation system (Section 14.3), or obtaining water from other sources. It has been noted that in some cases, water softeners will reduce the uranium concentration by a small amount. Reverse osmosis systems may also be effective in uranium removal.

In natural waters the type of uranium of concern is the uranyl ion. Uranyl salts dissolve easily in water and produce an objectionable taste and colour when they exceed a concentration of 5 mg/L as uranium. At considerably higher levels, ingestion of water containing uranyl ions may result in possible kidney damage. The recommended drinking water limit in Nova Scotia is 0.10 mg/L uranium. This limit is based on the chemical properties of the uranyl ion rather than on radioactivity.

Radon gas, the daughter product of uranium decay, may also be a problem in some wells. This heavy gas is slightly radioactive and could be dangerous if allowed to accumulate in unventilated areas. The use of aerators on faucets and adequate ventilation of bathrooms and basements are the best precautions against radon gas build-up. Wells should be drilled out-of-doors and should have the well casing extend to the surface of the ground (pitless adaptor construction) where any gas build-up can be easily vented.

13. HYDROCARBONS AND OTHER ORGANIC CHEMICALS

With an ever increasing frequency, wells are becoming contaminated with such man-made chemicals as gasoline, fuel oil, perchloroethylene (PCE, drycleaning solvent), phenols (from creosote) or trichloroethylene (TCE, degreasing agent). Where the well is contaminated with any man-made chemical, the initial idea is to remove the source of the contamination. The treatment methods described in the following sections should be regarded as temporary. Many of the methods are new and have not been fully tested.

13.1 Hydrocarbons

The term hydrocarbons as stated here includes fuels such as gasoline, diesel fuel or stove oil. In almost every instance, homeowners notice the presence of these chemicals in their water by the strong odour, particularly in the hot water. The nose can detect gasoline down to concentrations of 0.5 parts per billion (ppb) and fuel oil down to 1.0 ppb. Standard analytical techniques can only measure to 50 ppb.

Generally any concentration of hydrocarbon makes the water unacceptable for drinking. Constituents of fuels such as xylene, toluene and benzene have been associated with cancer. Sampling for hydrocarbons requires special glass bottles available through the Department of Health or the Department of the Environment.

13.2 Phenols

The main source of phenols in well water is creosote used for wood preservation. Phenols have a strong taste and odour. The maximum acceptable concentration for phenols is 0.002 mg/L (2 ppb) and is based on aesthetic considerations.

13.3 Perchloroethylene and Trichloroethylene

Both perchloroethylene (PCE, tetrachloroethylene) and trichloroethylene (TCE) are organic solvents. They are designed to

dissolve fats and greases. PCE is most frequently used for drycleaning but is also present in some household degreasers. Trichloroethylene is primarily used for degreasing by industry.

At the concentrations which tend to occur in well waters PCE and TCE are not detectable by odour or taste. The suggested World Health Organization drinking water limits for PCE and TCE are 10 and 30 ppb respectively. PCE and TCE have been associated with liver cancer amongst laboratory animals consuming large quantities of the chemicals..

13.4 Treatment

The following methods have been suggested for the removal of the above-mentioned chemicals although their effectiveness has not been fully tested.

13.4.1 Granular Activated Carbon

Granular activated carbon (GAC) or charcoal filters have proven to be effective in removing hydrocarbons and other organic chemicals. The life of the bed will depend on the concentration of contaminant present and the amount of water used. Results of studies by the University of Maine on the life of GAC units are shown on Table 2 (Lowry and Lowry, 1985). Often several GAC units are added in sequence to minimize the frequency of bed replacement on a single filter unit. Sometimes pretreatment for iron and manganese removal is required in the case of gasoline contamination. Gasoline may cause these minerals to 'dissolve' out of soil or bedrock. Household-sized GAC units cost $1000. A typical bed replacement cost is $75.

13.4.2 Reverse Osmosis

Reverse osmosis (R.O.) units are apparently capable of removing the aforementioned chemicals. R.O. units are available to treat the entire household water supplies. According to Lowry and Lowry (1985) some of the problems associated with R.O. units is that they use a water volume of at least four times the normal supply and produce waste water that is at a higher contamination level than the raw water. Therefore, there is a

possibility of contaminating your well via your domestic septic system, as well as the original source of the contaminant. R.O. units would not require the periodic bed replacement that is required by granular activated carbon units.

13.4.3 Aeration

Lowry and Lowry (1985) have developed an aeration system for removal of volatile organic chemicals such as those described. The system consists of a series of vessels in which air is pumped into the water. The water passes from vessel to vessel until all of the contaminant has been driven off. The contaminant is vented to the air, a possible problem with some explosive or odourous contaminants. The system is capable of treating water containing several hundred mg/L of gasoline.

The Lowry's treatment system has several advantages over the granular activated carbon system, the most important of which is the lower operating cost. There is no activated carbon bed to replace. They estimate the installation cost to be $2500 (U.S.) to $2800 (U.S.). The system is most cost-effective in highly contaminated water systems.

TABLE 8

Bed Life Estimates for Granulated Activated Carbon Treatment Units

Bed Size	Gasoline Influent Concentration[1]			
	1.0 mg/L		15.0 mg/L	
	days	Imp. gallons	days	Imp. gallons
1.2 cu.ft.	20	2128	7	744
1.8 cu.ft.	20	2128	7	744
2.5 cu.ft.	90	9600	10	1064

[1]20 ppb breakthrough criteria

14. COLOUR

Most colour in groundwater is caused by the presence of iron and/or manganese. Accordingly, the colour problem is dealt with by the removal of the iron and/or manganese. However, some colour is not caused by the presence of iron and manganese. It may be caused by the presence of humic acids.

Humic acids are the result of the breakdown of leaves and plants into a black humus soil. Water containing humic acids is water that has percolated through these soils. Usually the deeper soils will filter out the humic acids. However, in areas where there is little soil or it is boggy or where the well is improperly cased into bedrock, humic acid containing waters may enter wells. Humic acids give the water a clear brown colour similar to weak tea. Generally, they are not known to be harmful. However, chlorination of water containing humic acids may form cancer-causing materials (Meier et al, 1984).

Humic acids can be removed by charcoal filters (Section 10.1), by ozonation (Section 2.2), or by means of coagulants (Section 11.1).

15. SODIUM

Sodium is the result of dissolution of table salt (salt is sodium chloride). Of late, the sodium concentration in drinking water has become a concern for many people. Yet the intake of sodium from drinking water is only a small portion of that consumed in food. For instance it is estimated that milk contains 520 mg/L of sodium (U.S. Department of Agriculture). Tomato soup contains 3900 mg/L of sodium.

The suggested drinking water limit for persons on salt-restricted diets is 20 mg/L sodium. Excessive amounts of sodium in diets has been related to the development of high blood pressure and hypertension (National Academy of Sciences, 1977).

One source of sodium that seems to be of public concern is water softeners. Water softeners will add sodium to drinking water. The amount

of sodium added is related to the hardness of the water, i.e., the harder the water, the more sodium added by the softener. When water softeners are used to remove iron and manganese, less sodium is added to the water than if the softener was actually used to soften the water.

Sodium can be removed from drinking water by means of reverse osmosis units or distillation units.

15.1 Reverse Osmosis

Due to the small size of the sodium atom, reverse osmosis (R.O.) units are not 100% effective in the removal of sodium from drinking water. The effectiveness of the unit ranges from 60% to 95%. The effectiveness of the unit is dependent on the type of membrane and the quality of the water. R.O. units are discussed in Section 7.1

15.2 Distillation

Distillation is another option available for the removal of sodium and many other minerals from drinking water. These units operate by boiling the water, gathering the resulting steam and cooling and condensing it to liquid water again. Bacteria are destroyed by the heat and minerals are left behind in the boiler. The process results in nearly pure water.

Distillation's main advantage is its simplicity of operation. No pretreatment is required. The units produce approximately 27 litres (six gallons) of drinking water per day. Essentially all the minerals in the water are removed, making the unit suitable for treatment for practically any water quality problem. A study of the system by the Nova Scotia Department of Health (Don Feldman, Personal Communication, 1985) revealed that build up of minerals on the boiler was not a problem. The main disadvantages to distillation are the power consumption and noise the unit can make. The unit tested by the Department of Health was a 1000 watt unit that the homeowners kept in the basement because of the noise. It sold for approximately $1000.

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APPENDIX A

A PARTIAL LIST OF FIRMS DEALING WITH DOMESTIC WATER TREATMENT

NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT

Partial List of Firms Dealing with Domestic Water Treatment

COMPANY	REF. #	SERVICE CODE	PRODUCT CARRIED
Aquecol Water Conditioning Products 5 Emmanuel Drive Dartmouth, Nova Scotia (B3A 4M2) Phone: (902) 463-5821 President: Steve Burke	1	DMISR	Petwa-Aquecol
Atlantic Purification Systems Ltd. P.O. Box 877, 10 Ferguson Road Dartmouth, Nova Scotia (B2Y 3Z5) Phone: (902) 469-2806 Telex: 019 22590 General Manager: Kenneth V. Reardon	2	DMISR	AMF Cuno, Chem. Tech. CMS, Sanuril E.&.I. Filtersoft, Kinetico, Specialty Trojan Wallace & Tiernan
Better Water (N.S.) Ltd. Truro Heights, R.R.#1, Lower Truro Truro, Nova Scotia (B2N 5A9) Phone: (902) 895-4467/895-3418 President: Gordon P. McCulloch or Water Doctor, 1129 Sackville Drive P.O. Box 594, Lower Sackville B4C 3J1 Pres: Russell Lisson Phone: (902) 865-0952	3	DMISR	Lindsay
Culligan Water Conditioning Ltd. 91 Sackville Drive Lower Sackville, N. S. (B4C 2R3) (902) 865-0127/865-0003 Branch Offices: Middleton, Wolfville, Chester and Sydney President: James Fleck	4	DMISR	Culligan
Filtronics Inc. Water Treatment Ecoguard Systems Ltd. 2979 Oxford St. Halifax, N. S. (B3L 2W3) Phone: (902) 454-5824 Pres: A.A. MacDonald	5	DISR	Filtronic, Ultra-Pure Ultra-Oxide
Flowwater Products 2 Bluewater Road Bedford, Nova Scotia (B4B 1G7) Phone: (902) 835-7297 President: Mr. B. Cooke	6	DMISR	Erie

(Cont'd)

COMPANY	REF. #	SERVICE CODE	PRODUCT CARRIED
Rockingham Hardware Ltd. 192 Bedford Highway Halifax, Nova Scotia (B3M 2K1) Phone: (902) 443-2450 Sales Manager: Robert Stewart	7	DMISR	Ecodyne/Mec-O-Matic, Erie
Water Processing and Chemical Co. Ltd. Box 55 Bedford, Nova Scotia (B4A 2Y2) Phone: (902) 835-5000 President: R. L. Negus	8	DMISR	Duro, Wallace-Tiernan

Service Codes

D - Domestic (individual) supplies
M - Municipal, industrial, commercial supplies
I - Installs systems
S - Services systems
R - Recommends type(s) of systems and designs (some include free water test)
* - Chemical products only
** - Wholesale distribution

Unit	Company Reference Number
pump type feed pump	1,3,4,5,6,7,8
aspirator feeders	2,3
tablet hypochlorinators	1,2,6
pot-type feeders	2,4,8
water softeners	1,2,3,4,6,7,8
ozonation	2,3,4,5
greensand filter	1,2,3,6,7,8
tank-type neutralizing filter	1,2,3,4,5,6
reverse osmosis	1,2,3,4,5,7
dealkalizer	1,2,4,6,8
deionization or demineralization	1,2,3,4,5,6,8
activated charcoal filters	1,2,3,4,5,6,7,8
oxidation by aeration	2,4,5,6,8
sedimentation	1,2,3,4,5,6,8
sand filters	1,2,3,4,5,6,7,8

This list has been compiled for public information and assistance only. The N.S. Department of the Environment does not undertake to make or does it assume any responsibility for an evaluation of a particular firm's qualifications and services. It is the responsibility of the client to make his/her own evaluation and selection.

APPENDIX B

Laboratory Facilities

Nova Scotia Department of Agriculture and Marketing Laboratory, Truro, Nova Scotia, Phone: 895-1571 - ext. 156.

Environmental Chemistry, Division of Clinical Chemistry, 5788 University Avenue, Halifax, Nova Scotia. Phone: 428-3466.

Nova Scotia Research Foundation Corporation (N.S.R.F.C.), Fenwick Street, Dartmouth, Nova Scotia. Phone: 424-8670.

Environmental Chemistry Prices

Test	Price (1985)
General Analysis (G.A.)	$40.25
G.A. and Metal Scan	$49.75
Uranium	$20.00
Hydrocarbon	$13.00
Arsenic	$5.00

APPENDIX C

Disinfecting the Water Supply

Chemical disinfection or chlorination is essential for new or repaired wells, cisterns, springs, pumps and pipes. Bacteria is introduced during the construction or repair. Disinfection is the final step after all defects in location and construction have been corrected and before samples are collected for bacterial examination. Improperly located and constructed water supplies are never safe even though disinfected as outlined below. Disinfection cannot be relied on for one hundred percent destruction of harmful bacteria.

What to Use

Dry Material
(a) Chloride of lime. About 35% available chlorine.
(b) High test Calcium hypochlorites (B.K.-H.T.H.-Perchloron) 50%-70% available chlorine. Regular calcium hypochlorite has 25% available chlorine.

Solutions
(c) Sodium hypochlorites. Usually available as a laundry bleach in grocery stores. It has many trade names. Labels will show 3% available chlorine.

How Much to Use

Make a 20-litre or 5-gallon batch of stock solution for water treatment as follows:

(a) Chloride of lime - 780 grams in 20 litres of water (2 lbs in 5 gallons)
(b) High test hypochlorite - 390 grams in 20 litres of water (1 lb in 5 gallons) for 70% available chlorine and 540 g in 20 litres water (1 lb. 6 oz. in five gallons) for 50% available chlorine.

(c) 3% laundry bleach - 7 litres in 13 litres of water (two gallons in three gallons of water)

(d) 5% laundry bleach - 4 litres in 16 litres of water (one gallon in four gallons of water).

Mix solution thoroughly.

The above stock solution is about 12,500 parts per million on 1.2% by weight chlorine. To obtain an applied concentration of 50 ppm four litres or one gallon of stock solution should be used to treat 1000 litres or 250 gallons of water.

To summarize and clarify the discussion on how much bleach or javex to use on your well:

1. Measure the depth of water in your well and calculate the volume of water present using the following table.

2. Add one litre of liquid laundry bleach or javex for every 60 gallons of water in the well ... 1 litre bleach/60 gallons of water or 1 litre bleach/275 litres of water.

Number of litres of water per metre of water in the well:

Well Diameter, cm	L/m	Well Diameter, cm	L/m	Well Diameter, cm	L/m
10	78.5	35	961.6	70	3846.5
15	176.6	40	1256.0	75	4415.6
20	314.0	45	1589.6	90	6358.5
25	490.6	50	1962.5	120	11304.0
30	706.5	60	2826.0	150	17662.5

Number of Imperial Gallons of water per foot of water in the well:

Well Diameter, in.	Gal./ft.	Well Diameter, in	Gal./ft.	Well Diameter, in.	Gal./ft.
4	0.54*	15	7.65	27	24.77
6	1.22	16	8.70	30	30.59
8	2.17	18	11.01	36	44.05
10	3.40	20	13.59	42	59.95
12	4.90	22	16.45	48	78.30
14	6.66	24	19.58	60	124.02

*To convert to U.S. Gallons, divide by .833

Procedure to Follow

After your well has been tested for yield by blowing or bailing and the water is clear and free of turbidity:

1. Pour one-half the batch into the drilled well between the drop pipe and the outer casing, or directly into the dug well, cistern or reservoir. The solution may be poured or siphoned through the air vent pipe.

2. Start pump and open all taps until water from each tap has distinct odour. Stop pump and add remainder of batch.

3. Allow to stand from 12 to 24 hours.

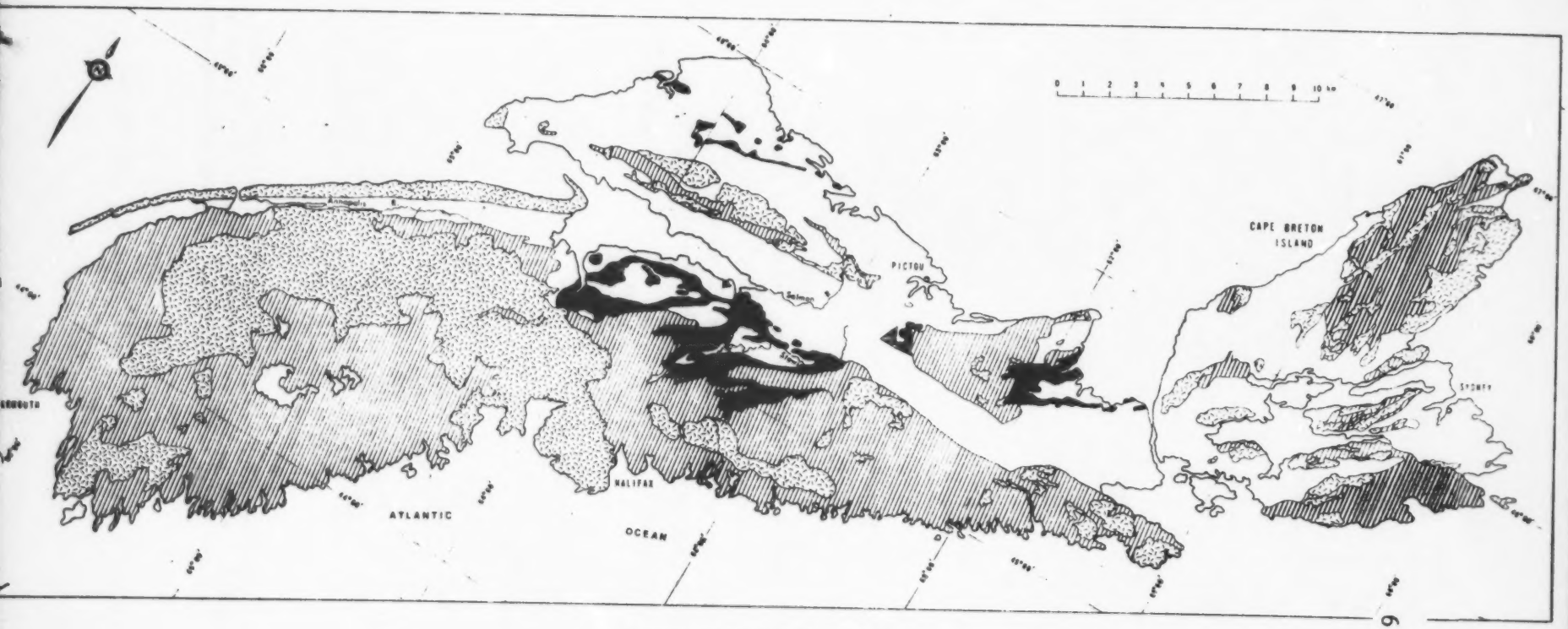
4. Pump the supply to waste until odour of chlorine disappears.

5. Request your Public Health Department to collect samples before using the water.

If possible, have additional check samples taken after two weeks. Remember, disinfection of an improperly located or constructed supply will not insure its safety.

APPENDIX D

FIGURES



Geology and Groundwater Quantity/Quality

ROCK TYPE	WELL YIELDS (lgpm)		WATER QUALITY PROBLEM
Igneous (ie. granites)	4	1–40	iron, manganese, uranium & acid water
Metamorphic (ie. slates, quarzites)	3-5	1–12	iron, manganese, arsenic & acid water
Carbonate sedimentary (ie. limestone)	6	1–100	hard water, sulphate, high TDS, iron & salt
All other sedimentary (sandstones, shales)	8	3–20	good quality, some sediment, iron & manganese
Surficial deposits (sands, gravels, clays)	variable		iron, manganese, acid water

Source: Geologic map of the Province of Nova Scotia
Department of Mines and Energy
Compiled by J.D. Keppie, 1979

Figure 1

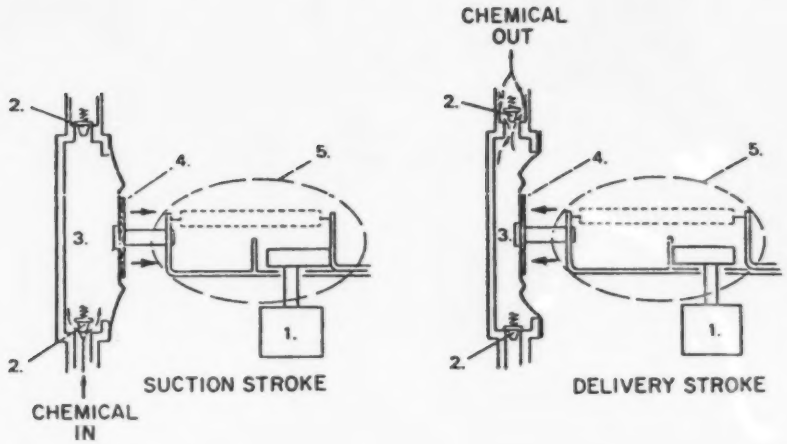


Figure 2. A common type of positive-displacement feeder. As the diaphragm (4) is pulled back, the volume of the chamber (3) is increased. A partial vacuum is formed, pulling the liquid through the lower check valve (2) and into the chamber. The diaphragm then moves forward, the lower check valve closes, and the liquid is forced through the upper check valve (2) to the point of injection.*

* Lehr et al., 1980, p. 142.

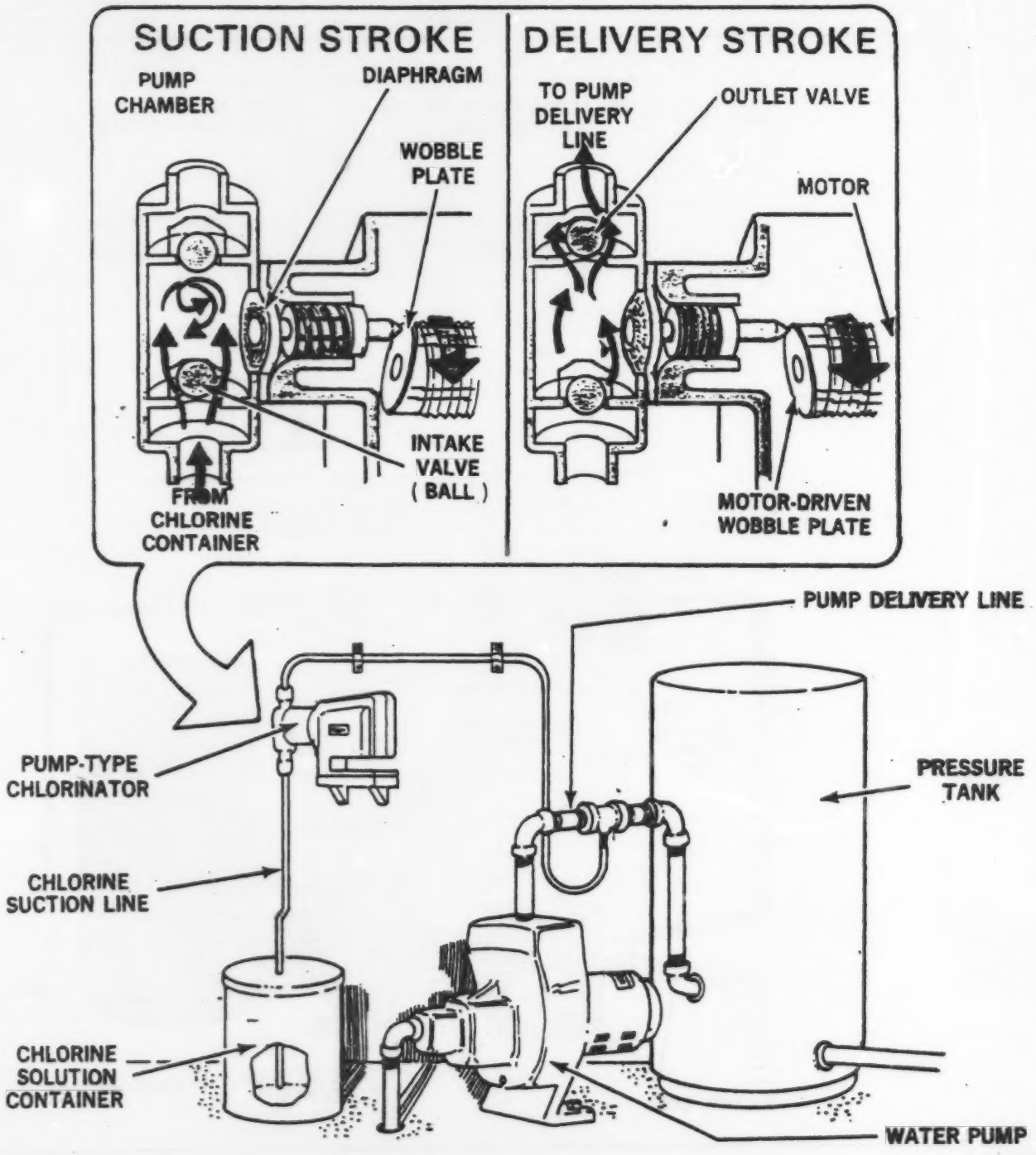


FIGURE 3. Pump-type diaphragm chlorinator driven by an electric motor. Chlorinator operates continuously while water pump is in operation. It is positive acting — delivering a fixed amount of chlorine solution with each discharge stroke.*

*Henderson, 1973, p. 35.

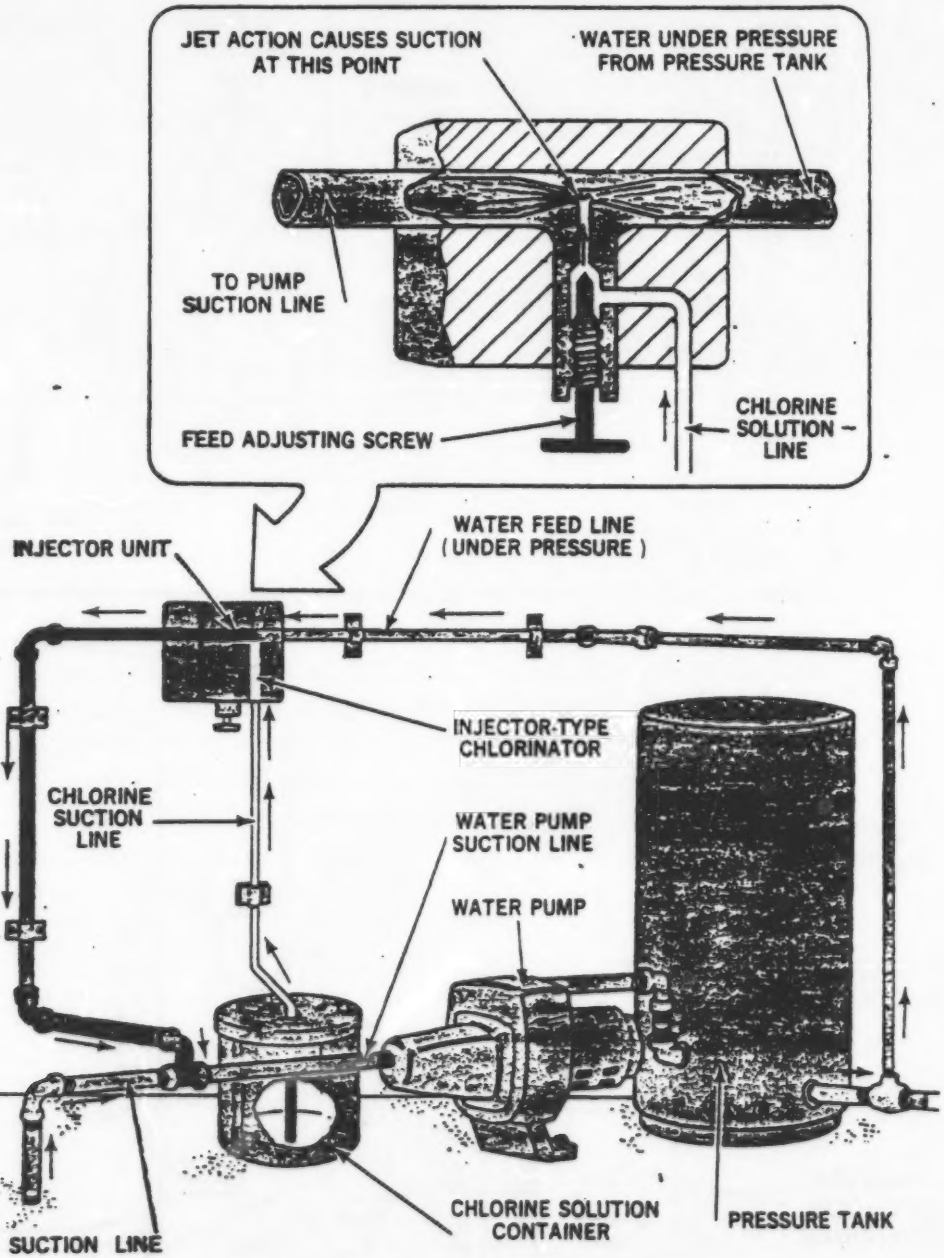


FIGURE 4. Injector-type chlorinator. Chlorine solution is drawn by jet (injector) action into the water-supply s

*Henderson, 1973, p. 36.

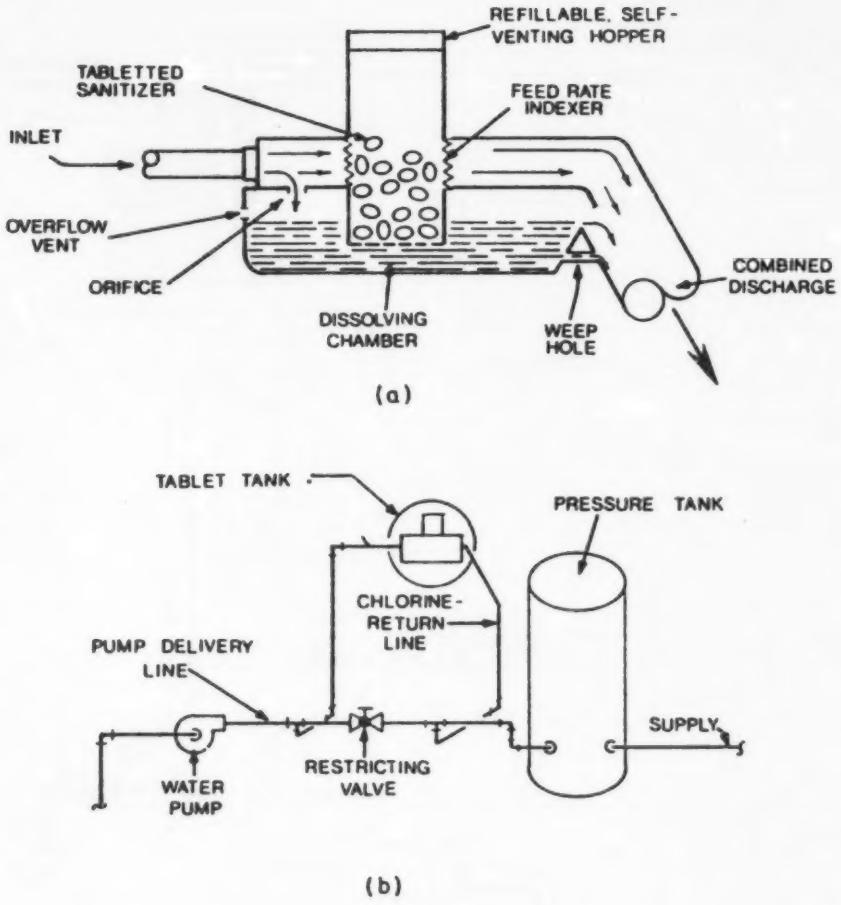


Figure 5. Tablet hypochlorinator.*

* Lehr et al., 1980, p. 146.

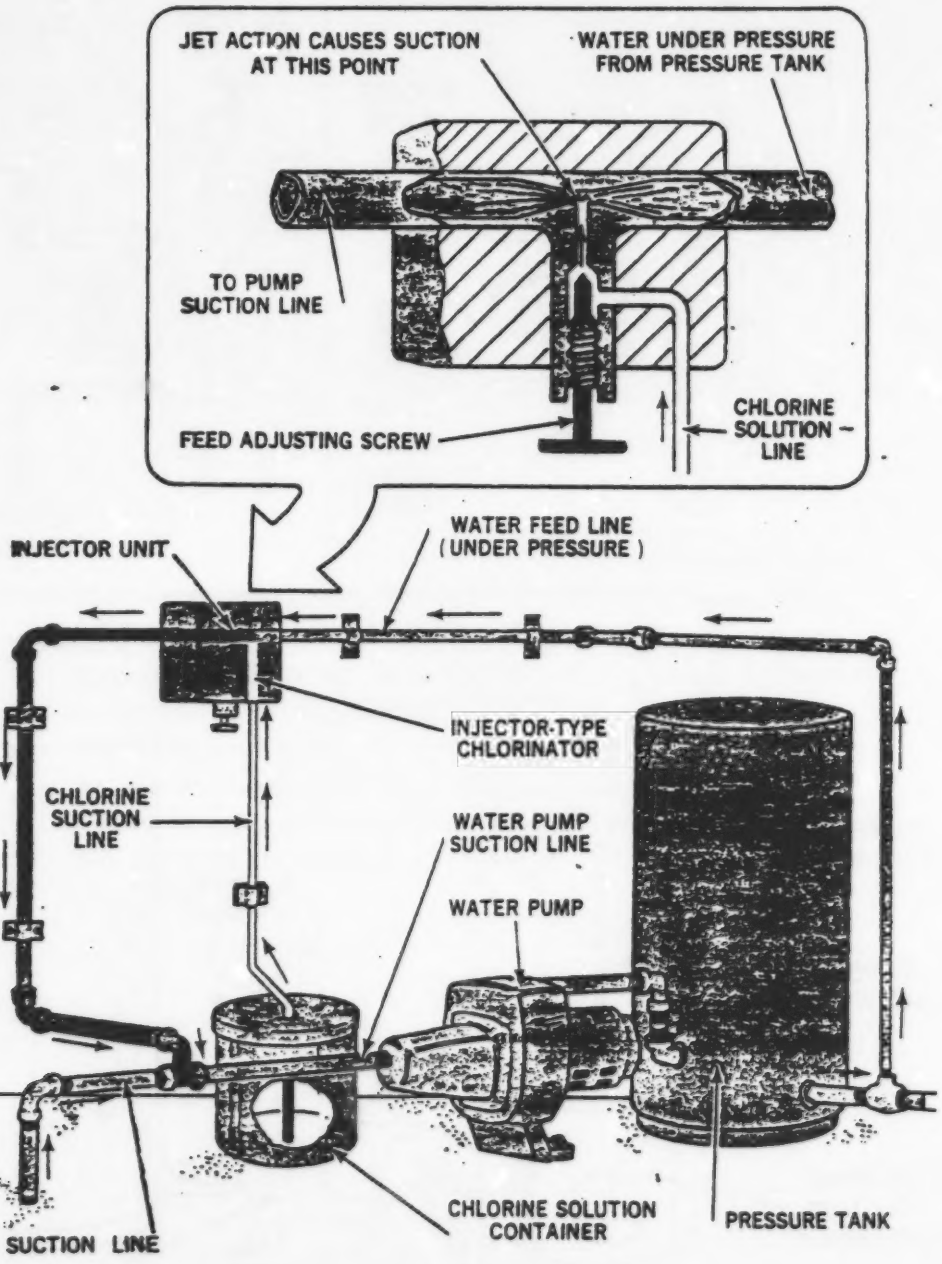


FIGURE 4. Injector-type chlorinator. Chlorine solution is drawn by jet (injector) action into the water-supply system.

*Henderson, 1973, p. 36.

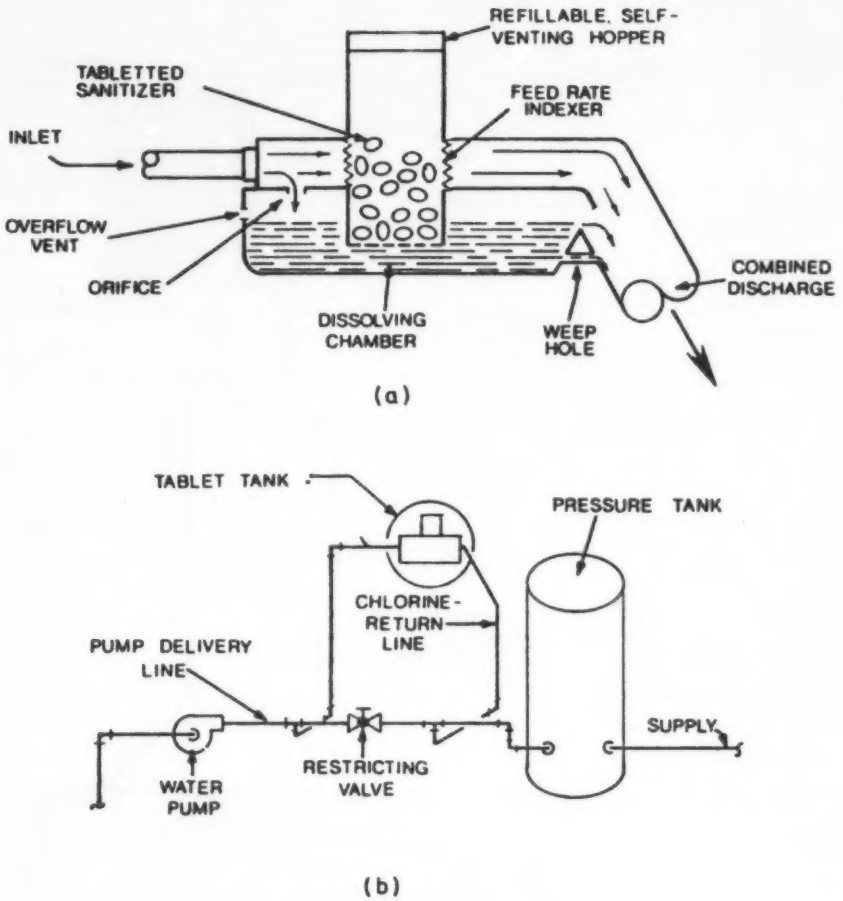


Figure 5. Tablet hypochlorinator.*

* Lehr et al., 1980, p. 146.

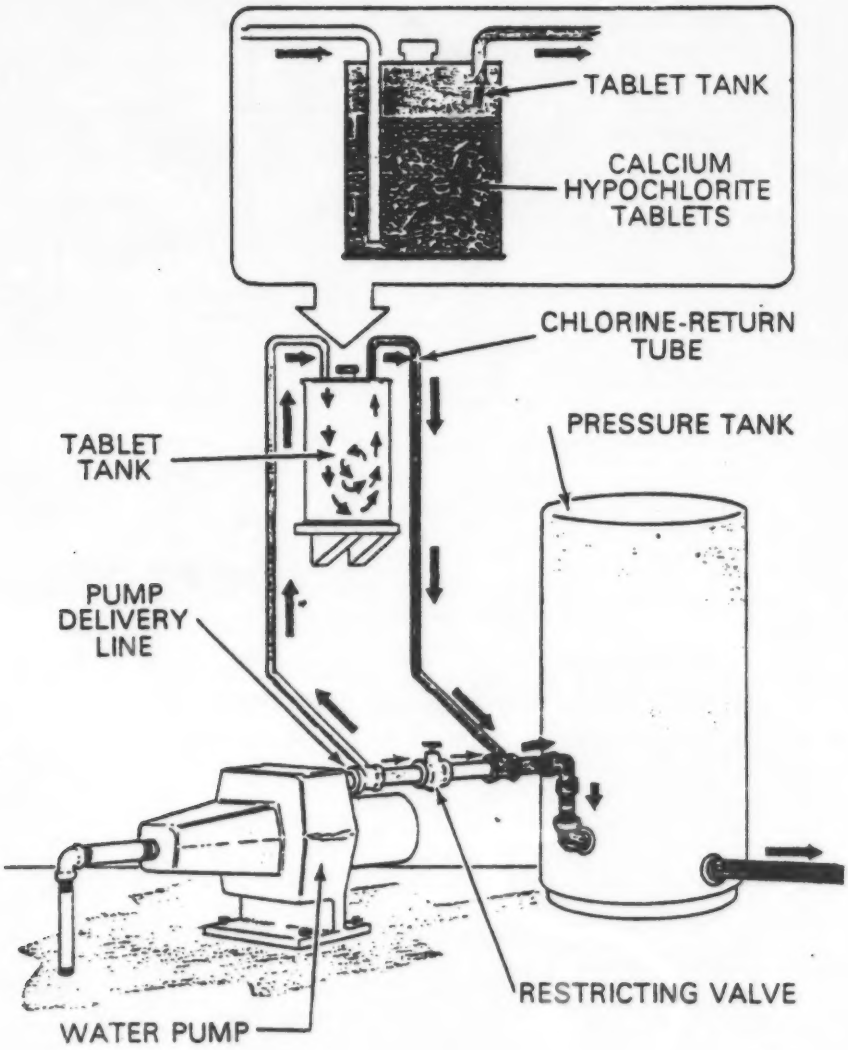


FIGURE 6. A tablet-type chlorinator bypasses water through a tank containing calcium hypochlorite tablets. The water dissolves a portion of the tablets and is returned to the pump delivery line ahead of the pressure tank.*

Henderson, 1973, p. 37.

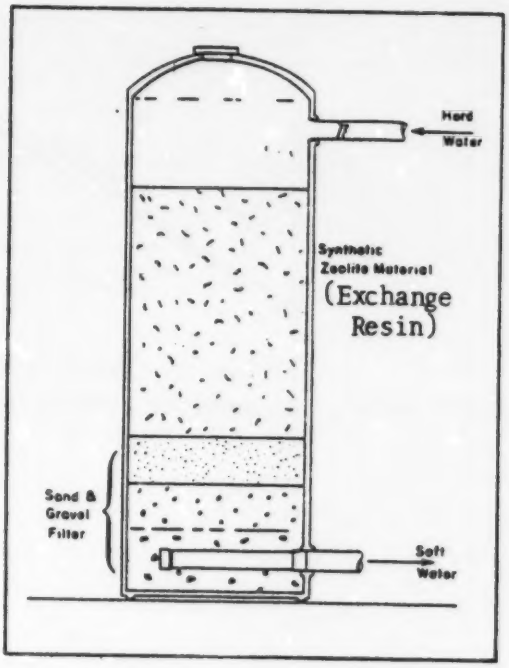


FIGURE 7. WATER SOFTENER.

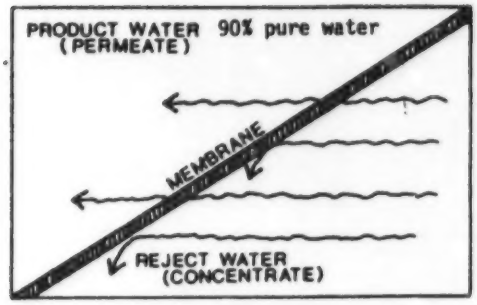


Figure 8. Water treatment with an osmotic membrane.[1]

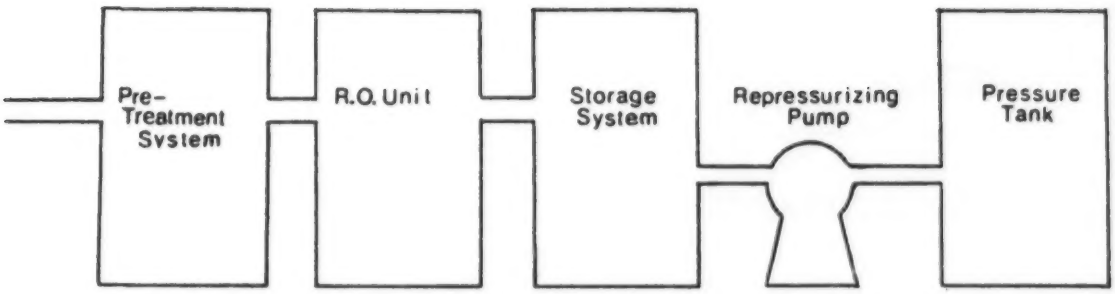


Figure 9. Organization of a water-supply system with a reverse osmosis unit.[2]

[1]Lehr et al., 1980, p. 184.
[2]Lehr et al., 1980, p. 185.

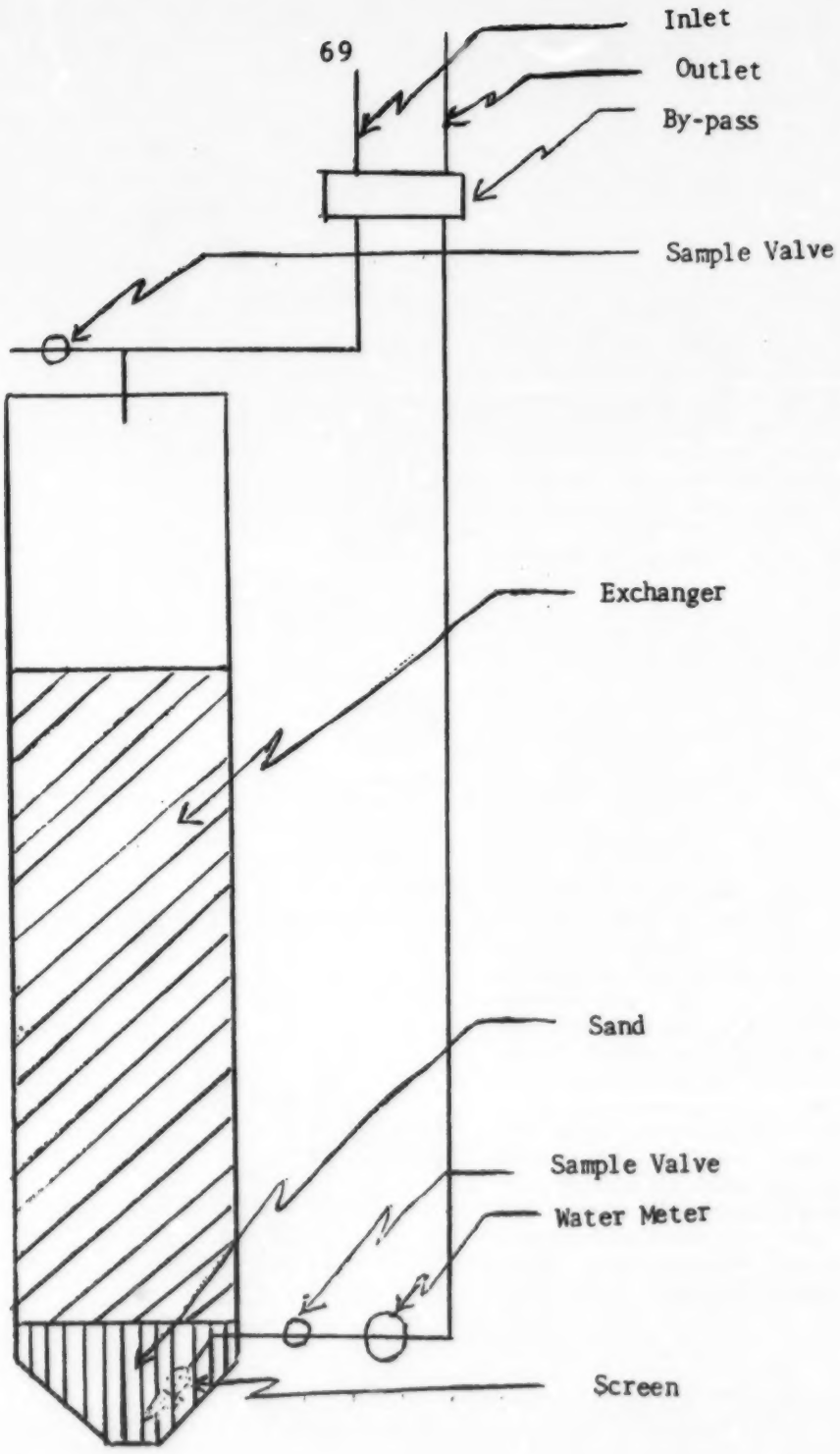


Figure 10. NSRFC research unit for removal of arsenic from water.

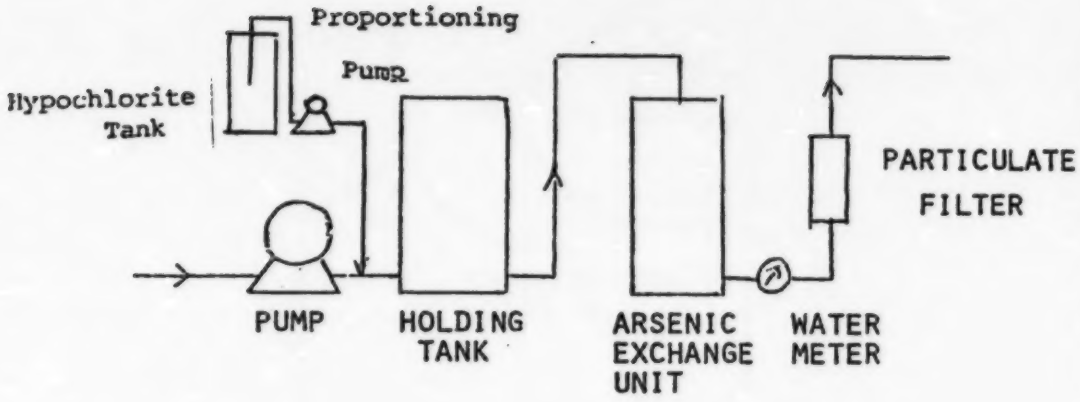


Figure 11. Mode of installing arsenic exchange filters.

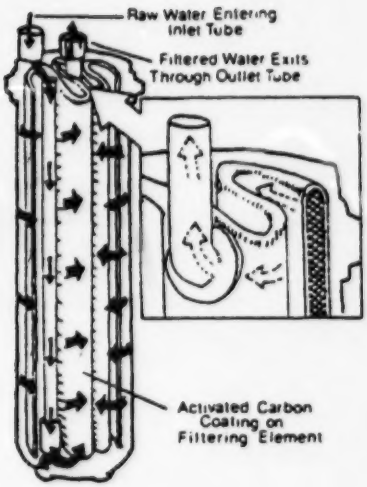

Raw Water Entering Inlet Tube
Filtered Water Exits Through Outlet Tube
Activated Carbon Coating on Filtering Element

Figure 12. One model of cartridge-type activated-carbon filter. Water is filtered as it passes from the outside of the filter element into the inner area. The inset shows how filtered water inside the element is collected and discharged through a special outlet. (*From: American Assoc. for Materials, 1973.* "Planning for an Individual Water System.")*

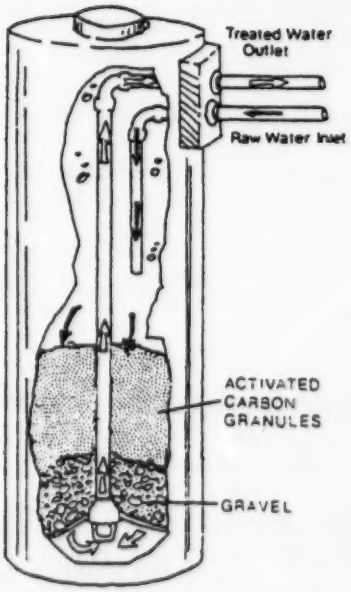


Figure 13. Activated-carbon-bed-type filter in the service mode of operation. Water flows through the control valve, down through the activated-carbon bed. The activated carbon will adsorb chlorine and other taste- and odor-producing organic matter until its capacity is exhausted. The filtered water then flows up through the distributor system, back through the valve, and to the water-supply system. Black arrow indicates unfiltered water. White arrow indicates filtered water. (*F. E. Myers and Bros., Co.*)*

*Lehr et al., 1980, p. 114.

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